Letters to the Editor

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On the Possibility of Observing Beat Frequencies between Lines in the Visible Spectrum

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IF two waves of very nearly the same frequency are superposed, the peak amplitude of the combination oscillates in magnitude with a frequency equal to the difference of the two original frequencies, giving rise to so-called beats. It is to be expected that under the proper circumstances such effects should be observable with light waves.

Consider two spectral lines centered at frequencies f_1 and f_2, whose widths are each δ. In each line the electric vector of the light is a superposition of an infinite number of components whose phases and amplitudes determine all details of the time variation of the electric vector. Most of the energy in the line is included in a frequency band equal to the width, and within this band the phases of the various components are random. Nonetheless the vibrations of the electric vector bear a certain resemblance to a sine wave. At any instant the various components of the line f_1 have definite phase relations, which will be retained for a time interval τ so short that the change in phase of the frequency $f_1-\delta/2$ differs by only a fraction of a radian from the change in phase of the frequency $f_1+\delta/2$. In other words, for time intervals τ small compared to $1/\delta$, the electric vector of the line vibrates much like a pure sine wave of frequency f_1. If f_1 and f_2 are polarized in the same plane and superposed, they will show beats, provided that the time intervals during which f_1 and f_2 retain their periodicity are large enough to include a reasonable number of beats. Writing $f_2-f_1=\Delta$, this condition can be expressed $\Delta>2\delta$. The beats can also be considered as resulting from the combination of each component in f_1 with each component in f_2, producing a beat pattern made up of frequencies lying in a band of width 2δ about frequency Δ. Thus the condition $\Delta>2\delta$ assures a relatively well-defined beat-frequency spectrum.

Line widths in the visible region can be made as small as 10^9 cycle/sec. Well-defined beats can therefore be produced with a Δ of 10^{10} cycles/sec., which is within the range of present day UHF techniques. To detect the beats or difference frequency a non-linear device of some kind must be employed. Such a device is a photo-surface, which yields a current proportional to the intensity of the incident light. The fluctuations in photo-current can be detected with a resonant cavity tuned to the frequency Δ. A projected apparatus for observing beat frequencies between lines in the visible spectrum is shown in Fig. 1.

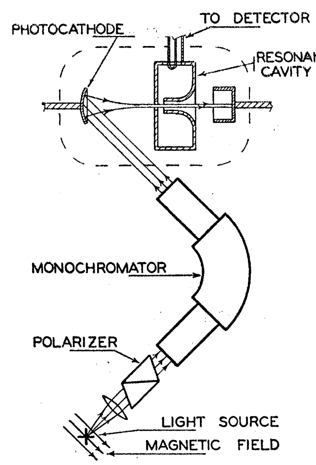

FIG. 1. Projected apparatus for observing beat frequencies. The polarizer eliminates the central component of the Zeeman spectrum of a line and the monochromator all lines except one, whose two outside components reach the photo-cathode with equal intensity.

Beats are produced between two Zeeman components of some chosen spectral line. This has the advantage of providing a variable frequency separation so that the cavity may have a fixed frequency, and of providing two lines of equal intensity, for which the beats are most pronounced. With fields of the order of 10,000 gausses, the two outside components of a normal Zeeman pattern provide separations of the correct order of magnitude.

Calculations indicate that the signal-to-noise ratio will probably be poor, the principal limitations being thermal noise in the cavity and the shot noise fluctuations in the photo-current. However, techniques for measuring signals against a high noise background have been developed,[1] and the prospects are fair that the beats will be detectable.

The possibility of performing this experiment is predicated upon the validity of certain assumptions regarding the nature of the photoelectric process. In particular, it is necessary to assume that the probability of emission of an electron from any point on the cathode is proportional to the average light intensity averaged over a time small compared to $1/\Delta$, and that the lifetime for photo-emission is small compared to $1/\Delta$. Evidently, if these assumptions are not satisfied, the photo-current will show little or no trace of the periodicity $1/\Delta$. Thus, detection of the beats should permit the inference that the lifetime for photo-emission is small compared to 10^{-10} second. Previous measurements have at most been able to show that this time is less than 3×10^{-9} second.[2]

[1] R. H. Dicke, Rev. Sci. Inst. **17**, 268 (1946).
[2] E. O. Lawrence and J. W. Beams, Phys. Rev. **32**, 478 (1928).